RECLAMATION

Managing Water in the West

A Framework for Assessment of Habitat Conditions to Inform Planning for a Pilot-Level Chinook Salmon Reintroduction Study

Shasta Dam Fish Passage Evaluation

U.S. Department of the Interior
Bureau of Reclamation

December 2013

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations and Acronyms

°C	degrees Celsius
GIS	geographic information system
GPS	geographic positioning system
IFPSC	Interagency Fish Passage Steering Committee
LWD	large woody debris
m^2	square meter
MWAT	maximum weekly average temperature
OHW	ordinary high water
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RPA	Reasonable and Prudent Alternative
sDVR	spatial digital video recorder

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Introduction

This technical memorandum was prepared as part of the U.S. Department of the Interior, Bureau of Reclamation's (Reclamation) planning process to develop a pilot-level study for salmon reintroduction in tributaries above Shasta Lake as is required by the reasonable and prudent alternative (RPA) specified in the National Marine Fisheries Service's *2009 Biological Opinion on long-term operations of the Central Valley Project and State Water Project*, as amended in 2011 (National Marine Fisheries Service Biological Opinion). Evaluation of habitat conditions above dams is required by the RPA "Action V-Fish Passage Program" as a priority action during the near-term phase of implementation of the RPA. The primary objective of these habitat assessments has been further specified by the Interagency Fish Passage Steering Committee (IFPSC), formed by Reclamation in 2010, to quantify and characterize the location, amount, suitability, and functionality of existing and/or potential spawning and rearing habitat above dams for reintroduction of salmon species listed under the Endangered Species Act.

Purpose

This technical memorandum describes an analytical framework for conducting a habitat assessment to inform development of the pilot-level Shasta Dam salmon passage and reintroduction study plan, within the 18-month duration for this study planning period. At this initial stage of the salmon reintroduction planning process, the primary purpose of the analytical framework proposed herein is to describe habitat availability and conditions relative to the requirements for the freshwater life stages of salmon species being considered for reintroduction rather than quantitatively predict the potential production of salmon above Shasta Dam. This approach will provide sufficient information for estimating the potential number of salmon spawners that could be released and supported by the existing habitat conditions for purposes of a pilot reintroduction study. The proposed analytical tools consist of a spatially-explicit stream classification procedure; a set of habitat suitability criteria derived from the literature; use of existing regionally relevant data and information, augmented with aerial videography and limited field verification surveys to fill data gaps; and assumptions concerning the potential distribution and use of habitat by salmon in portions of the watershed to which they have not had access for over 70 years.

This technical memorandum is organized to first provide a description of the conceptual approach to this habitat assessment, followed by detailed descriptions and rationales for the technical approach and methodologies to be

used. All sources of information consulted in formulating the habitat assessment approach and cited in this technical memorandum are provided in bibliographies included in the appendices. Furthermore, this technical memorandum is intended to serve as a working study plan and, as such, will be incorporated, with any amendments, into a final report on the habitat assessment.

Conceptual Approach

The analytic approach described herein uses a spatially-explicit framework to organize and integrate relevant information on habitat conditions in the streams of interest above Shasta Lake. Existing information will be used and augmented, as necessary, using data that can be derived by interpretation of aerial videography, with limited field verification of habitat attributes interpreted from the videography. Habitat suitability criteria to characterize the habitat conditions for the specific life stages of interest will be derived from the large base of scientific literature on the habitat requirements of anadromous salmonids, including criteria for Central Valley salmon in other tributary streams. Seasonal hydrographs and temperature records will be used to determine any seasonal limitations on the overall suitability of stream reaches for the various life stages of salmon. Data and information on current distributions and abundances of other fish species and predators in the vicinity of Shasta Lake and its tributaries will be compiled to assess the nature of potential ecological interactions with reintroduced salmon species.

A conceptual model of the relationships among habitat and other evaluation components, data inputs, and the associated logic for the habitat assessment are shown in Figure 1.

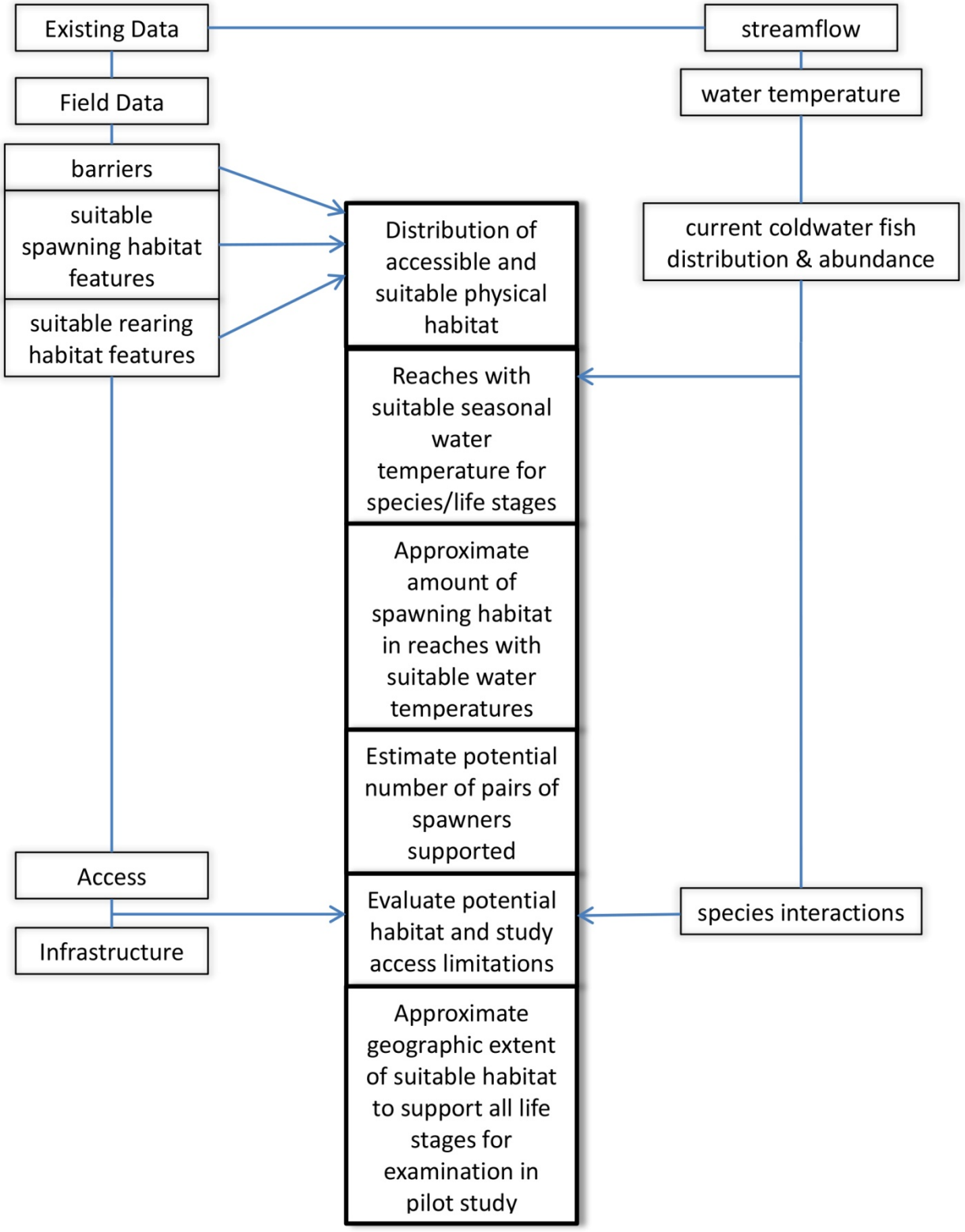


Figure 1. Conceptual Model for Assessment of Habitat Relationships of the Freshwater Life Stages of Chinook Salmon, with Approximation of Numbers of Spawners Supported by Habitat in Select Tributaries Above Shasta Dam

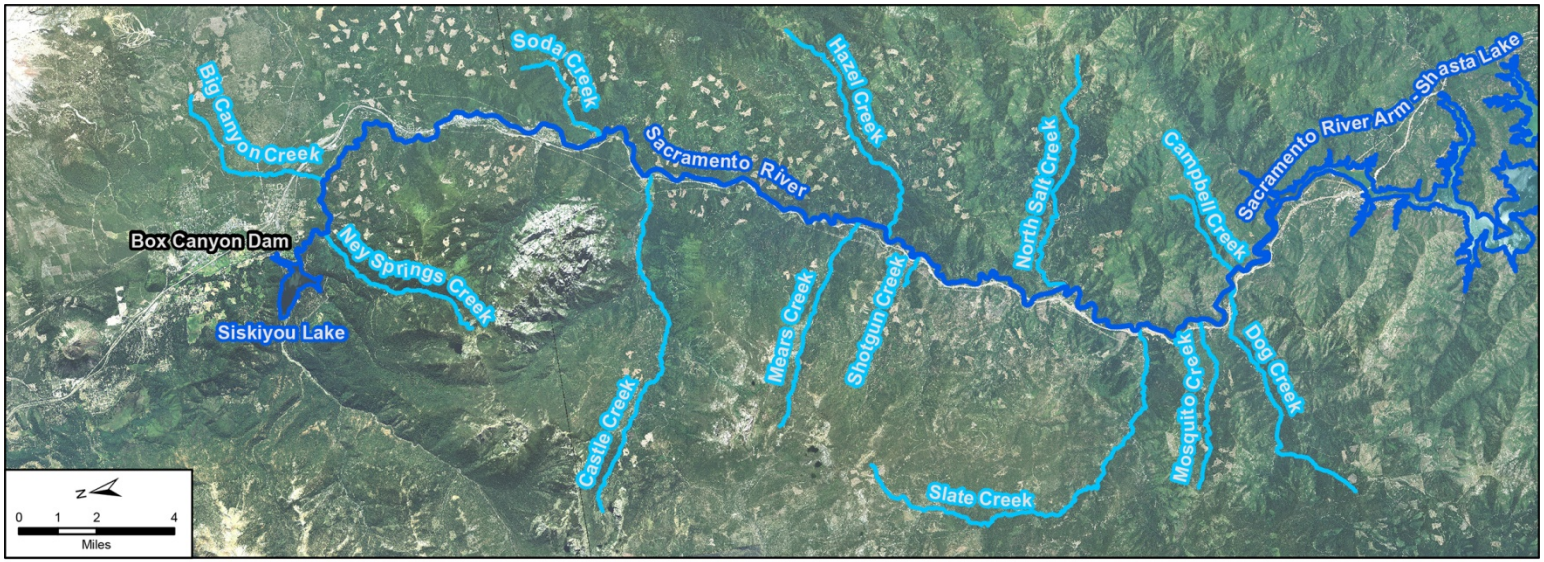
Analytical Tools and Methods

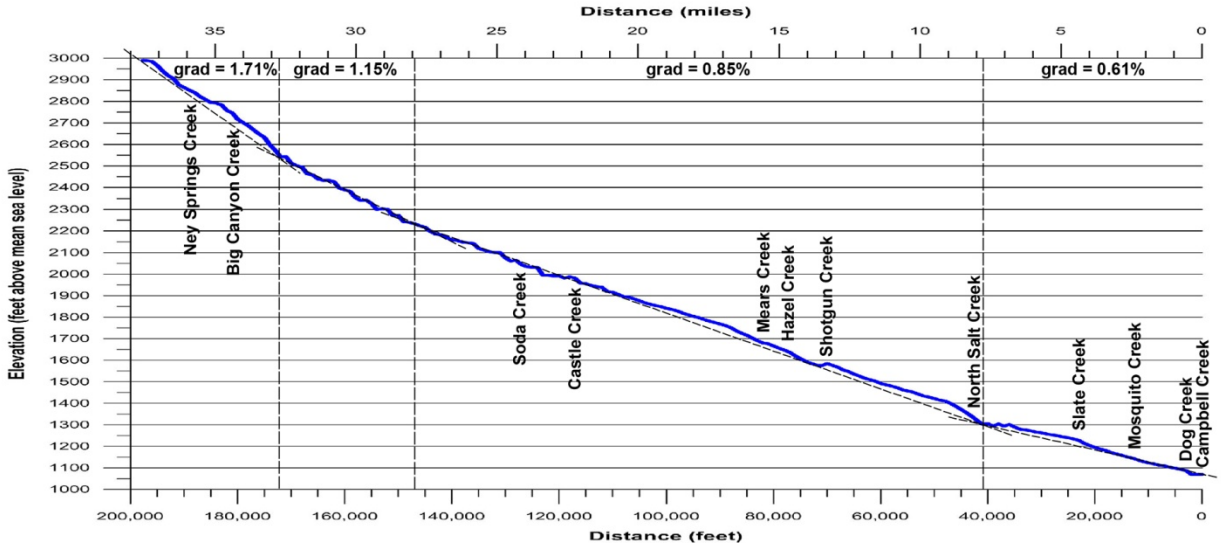
Geospatial Organization and Integration

A geographic information system (GIS) will be used to organize and integrate various types of habitat data and other relevant information on one or more geospatial base layers containing the stream reach network. This tool will provide for the examination and analysis of the spatial distribution, extent, and connectivity of freshwater habitats that would be suitable for anadromous salmonids, and any associated constraints, for planning the pilot-level reintroduction study. Habitat attribute data will be obtained from existing datasets and supplemented with field data to be collected as part of this assessment. The scaling of stream reach mapping units may be based on broad topographic characteristics, such as overall channel gradients; incremental changes in watershed area; geomorphic characteristics; human-modified channel or landscape features; and incremental distances from a reference point (e.g., river miles from the head of Shasta Lake). Figures 2 and 3 show examples of preliminary reach divisions based on broad-scale transitions in channel gradient along the main channels of the upper Sacramento and McCloud rivers.

Stream reaches will be represented in the GIS as line features imported from the National Hydrologic Database and/or reconciled and digitized along the center line of stream channels represented on 1:24,000 scale aerial photographic layers. Reach segments will be assigned identification numbers and habitat attributes will be linked by their geographic locations to applicable reach line segments in GIS datasets. The locations of other useful features such as landmarks, historic survey reference points and benchmarks, access points, and important infrastructure will be identified and entered into the GIS datasets, as needed for study planning.

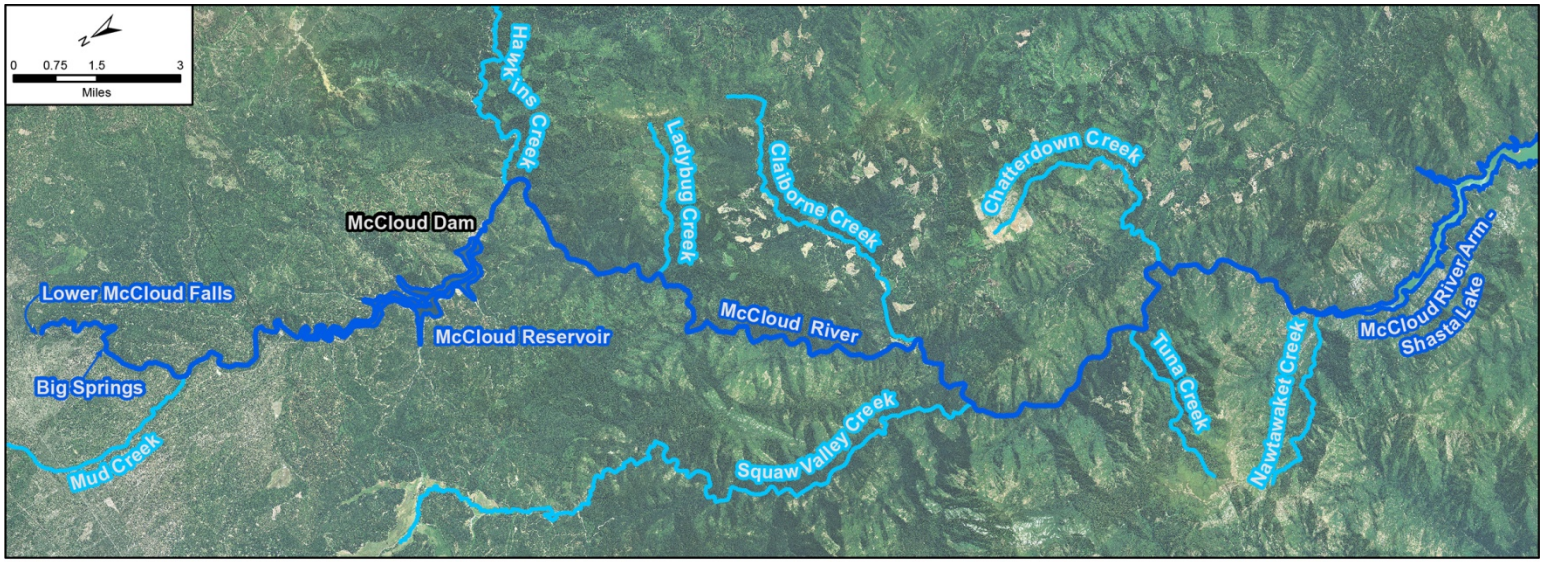
Habitat attributes and metrics will be presented as tabular and graphical compilations, with reference to spatial position along stream courses, and displayed in GIS renderings on the digitized stream reach layers, as appropriate.

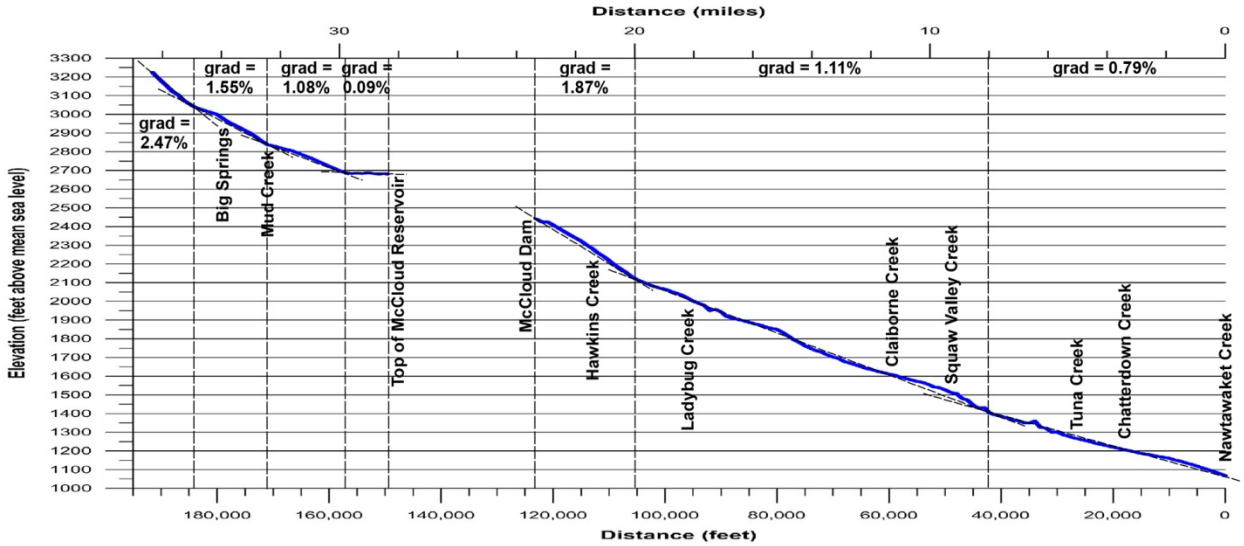




Note: Vertical lines delimit reaches based on changes in channel gradient

Figure 2. Sacramento River (Shasta Lake to Box Canyon Dam)





Note: Vertical lines delimit reaches based on changes in channel gradient

Figure 3. McCloud River (Shasta Lake to Lower McCloud Falls)

Habitat Attributes

A number of attributes and metrics for characterizing and assessing the condition of habitat relative to the freshwater life history requirements of Chinook salmon and steelhead were evaluated from a review of the literature. Several important review papers (Bjornn and Reiser 1991; Healey 1991; Cramer 2001; Kondolf et al. 2008; Miller et al. 2008) and habitat assessment guidance documents (Platts et al. 1983; McCain et al. 1990; Harrelson et al. 1994; Bain and Stevenson 1999; Frazier et al. 2005; Flosi et al. 2010) were consulted in identifying useful attributes for assessing habitat conditions. The attributes used in two recent habitat assessments conducted for anadromous salmonid reintroduction studies, including Burke et al. (2010) for the upper Deschutes River, Oregon and the Upper Yuba River Studies Program (2007) for the upper Yuba River, California were examined. Key attributes were identified that are applicable to reach-scale and landscape-level evaluation, which is the approach recommended for use in this habitat assessment, and were categorized as geographic, hydrologic, and physical habitat information, which are listed and described in Tables 1 and 2.

Table 1. Geographic and Hydrologic Attributes to be Considered in Assessment

Attributes	Parameter	Description
Access	Access locations	Description and location of developed and undeveloped public access and potential for private access to river
Infrastructure	Dams, diversions, weirs	Description and location of passable and impassable dams, weirs, and diversions on river and major tributaries
	Vehicular roads	Description and location of public and private roads adjacent to and crossing the river obtained from available county, state, and federal road inventories
	Railroads	Description and location of railroads adjacent to and crossing the river obtained from available county, state, and federal railroad inventories
	Bridges	Description and location of public and private bridges crossing the river obtained from available county, state, and federal road inventories
	Stormwater discharge	Description and location of municipal, industrial, state, and federal stormwater discharge points to the river obtained from available local, county, state, and federal inventories
	Wastewater discharge	Description and location of municipal and industrial, treated wastewater discharge points to the river obtained from available local, county, state, and federal inventories
	Stream gages	Description and location of stream gages along the river obtained from available state and federal inventories and records
Barriers	Natural barriers	Description and location of complete and partial barriers to fish migration on river and major tributaries
	Culverts	Description and location of road crossings with culverts that impose potential barriers to fish migration on river and major tributaries
Hydrologic	Flow regime	Statistical and graphical summaries of available flow records for river and major tributaries
	Temperature regime	Statistical and graphical summaries of available temperature records for river and major tributaries
Reach morphology	Channel type	Reach-scale channel classification following Montgomery and Buffington (1993)
	Gradient	Reach-scale channel gradient using 10 meter DEM and National Hydrologic Database GIS layers
	Major tributaries	Description and location of confluences of major tributaries

Key:
DEM – digital elevation model
GIS – geographic information system

Table 2. Habitat Attributes to be Considered in Assessment

Attribute	Parameter	Description
Channel morphometry	Habitat unit type	Riverine habitat types following those outlined in Flosi et al. (2010),including riffle, cascade, pool, glide, run, pocketwater
	Unit length	Length of habitat unit
	Width (base, OWH, bankfull)	Estimated average channel width at the typical base flow, ordinary high-watermark, and bankfull flow
	Depth (base, OWH, bankfull)	Estimated average channel depth at the typical base flow, ordinary high-watermark, and bankfull flow
	Channel confinement(valley width : bankfull width)	Ratio of the widths of the valley to bankfull(active) channel (confined, if ratio ≤2; unconfined, if ratio >2)
	Channel entrenchment(flood prone : bankfull width)	Ratio of widths of flood prone area to bankfull channel
Substrate	Dominant/subdominant bed substrate	Dominant and subdominant bed substrates (fines, gravel, cobble, boulder, bedrock)
	Fines (%)	Percentage of bed substrate ≤2 mm grain ϕ
	Gravel (%)	Percentage of bed substrate >2 mm and ≤64 mm particle ϕ
	Cobble (%)	Percentage of bed substrate >64 mm and ≤256 mm particle ϕ
	Boulder(%)	Percentage of non-bedrock substrate > 256 mm particle ϕ
	Gravel embeddedness in riffles	Estimated average proportion of gravel particles embedded by sand and silt, 0 to 5 % and quartiles for higher amounts
Cover	Dominant/subdominant cover types	Dominant and subdominant cover types, including depth, surface turbulence, boulders, submerged vegetation, overhanging vegetation, undercut bank, LWD
	Cover amount (proportion of surface area)	Amount of different cover types relative to surface area, in quartiles
	Riparian vegetation length	Percentage of unit length on each bank, in quartiles
	Riparian vegetation width	Percentage of unit width on each bank
	LWD (*Fq* by size classes)	Number of pieces of large wood (≥30cmϕ and ≥1.8mlong)
	Pool complexity/Shelter value	Rating system of Flosi et al. (2010) from 0 to 3 for relative quantity and composition of instream cover complexity
Habitat-specific features	Pool in proximity to spawning gravel	Pools with area of spawning gravel in associated tailout or adjacent US or DS habitat unit
	Area of suitable spawning gravel	Area of spawning gravel ≥3 m^2 located in riffle or pool tailout habitat feature at base flow stage and OHW stage
	"Deep pools" >0.6 m (juvenile salmon) ≥1.5 m (adult salmon)	Pools with a maximum depth of at least 0.6 m (juveniles) and 1.5 m (adults) estimated at base flow stage
	Maximum width of "deep pool"	Maximum width of "deep pools" at base flow stage

Key:
% – percent
ϕ – intermediate grain diameter
≥ – greater than or equal to
DS – downstream
Fq – frequency
LWD – large woody debris
m – meters
m^2 – square meters
mm – millimeters
OHW – ordinary high water
US – upstream

Literature-derived Habitat Criteria

Classification criteria based on relative preferences and habitat requirements of different life-stages of anadromous salmonids applicable to the selected habitat attributes were also derived from an extensive review of the literature. Information on Chinook salmon stocks from the Sacramento River and its tributaries were given priority, but the scope of our review also included habitat relationships for Chinook salmon throughout its range in California and the Pacific Northwest, but particularly from areas within the interior Porous Basalt and Cascades Range geologic provinces. Sources of information were obtained from 66 documents including book chapters, peer-reviewed scientific papers, published agency reports and guidance documents, and unpublished agency and consultant technical reports. Habitat criteria data in source documents were reviewed and screened for applicability to reach- and landscape-scale habitat assessments and a compilation of this review is provided in Appendix A. Each source document was catalogued and entered in a bibliographic database, which is summarized in Appendix B, and is available in electronic format.

Based on a screening of criteria with applicability for reach-scale habitat condition assessment, a classification scheme was modified from that used on the Deschutes River by Burke et al. (2010) for rating several of the key habitat attribute metrics for use in the upper Sacramento and McCloud rivers. This proposed classification scheme assigns "good," "fair," and "poor" ratings to metric value ranges for several of the life stage-specific habitat attributes based on our interpretation of data reviewed in the source documents (Tables 3 through 5).

The habitat attributes used for this assessment will be evaluated at a reach-scale using metrics expressed in units such as counts per reach, counts per fixed length (e.g., number per mile), proportions (in percentages) of reach lengths, proportions (in percentages) of channel widths, and estimated areas (e.g., area of suitably-sized spawning gravel). Metrics for each reach unit will be compared to the habitat criteria shown in Tables 3 through 5 and can be assigned a condition class rating. The condition classes will be codified as 1 = "poor," 2 = "fair," and 3 = "good" for each metric. Since each habitat attribute hierarchically comprises several metrics, condition ratings for attributes will be computed as the average of the condition ratings of habitat metrics within the attribute group, by life stage. An overall habitat condition rating for each life stage can be computed as the average of the attribute ratings for each reach. This will allow comparison of the distribution and overlap of general habitat suitability's for spawning and rearing life stages. Although this overall habitat condition rating can be computed and used for such comparisons, the underlying metrics and their associated condition ratings will allow identification of the potential for life stage-specific limiting factors in each

reach, which may require further evaluation during the pilot reintroduction study.

Table 3. Spawning, Egg Incubation, and Emergence Criteria

Attribute	Parameter	Good	Fair	Poor
Channel morphometry	Channel type	pool-riffle	plane bed	step-pool, cascade
	Gradient	1 to 3%	3 to 4%	≥4%
	Entrenchment (flood prone width : bankfull width)	≥2.2	1.5 to 2.2	≤1.5
	Channel depth	0.25 to 3.0 m	--	<0.25 m
Substrate (*before redd construction*)	subdominant bed substrate	gravel/cobble	gravel/fines	cobble/fines
	% gravel in riffles	>30%	15-30%	<15%
	% cobble in riffles	20 to 40%	10 to 20%; 40 to 70%	<10%; >70%
	% fines in riffles	≤10%	10-20%	>20%
	Embeddedness in riffles	<25%	25 to 50%	>50%
Habitat	ratio	40 to 60% pools with tailouts	20 to 40% pools	<20%; >60% pools
	Pool proximity to spawning gravel	adjacent	--	--
	Pool depth	>2.5 to 3 m	1.5 to 2.5 m	<1.5 m
	Spawning gravel area	>6 m^2	3 to 6 m^2	<3 m^2

Key:
% – percent
m – meters
≤ – less than or equal to
≥ – greater than or equal to
< – less than
> – greater than
m2 – square meters

Table 4. Rearing Criteria

Attribute	Parameter	Good	Fair	Poor
Channel morphometry	Channel type	pool-riffle	plane bed	step-pool, cascade
	Gradient	<1-2%	2-5%	>5%
	Entrenchment (flood prone width : bankfull width)	≥2.2	1.5 to 2.2	≤1.5
	Channel depth	shallow (0.10 to 0.25 m) for fry; progressively deeper for parr	--	--
Substrate	Dominant/subdominant bed substrate	cobble/gravel	gravel/cobble	gravel/fines
	Gravel (%)	≥15%	5 to 15%	<5%
	Cobble (%)	≥15%	8 to 15%	<8%
	Fines (%)	≤10%	10 to 30%	>30%
	Embeddedness	≤25%	25 to 50%	>50%
Cover	Dominant/subdominant cover type	boulder/LWD/overhead	--	--
	Overhead cover (% of surface area)	≤30%	10 to 30%	<5%
	Boulder (%)	≥20%	5 to 20%	<5%
	LWD (Overall *Fq*/100 m)	≥20	10 to 20	<10
	Shelter (total cover) value (0-3)	3	2	0 to 1
Habitat	riffle ratio	40 to 60% pools/glides	20 to 40% pools/glides	<20%; >60% pools
	Large, deep pool *Fq* (>0.6 m deep, ≥9 m wide)	≥50% of pools	20 to 50% of pools	<20% of pools
	Pool complexity/shelter value[a]	good	fair	poor

Note:
[a] See pool/shelter complexity table for description of rating factors.

Key:
% – percent
≤ – less than or equal to
≥ – greater than or equal to
< – less than
> – greater than
Fq – frequency
LWD – large woody debris
m – meters

Table 5. Pool Complexity/Shelter Value Rating

Complexity Rating	Attributes
Good	Deep with considerable cover
	Depth > 0.6 m (≤ 10m wetted width stream)
	Depth > 1 m (> 10m wetted width stream)
	Criteria Conditions:
	≥ 3 key pieces of LWD, plus submerged vegetation and small wood
	Undercut bank > 20 %
	Boulders > 15 %
	Bubble curtain
Fair	Moderate depth and cover
	Depth ≥ 0.6 m (≤10m wetted width stream)
	Depth ≥ 0.6 to 1.0 m (> 10m wetted width stream)
	Criteria Conditions:
	1 to 2 key pieces LWD, plus small wood present
	Undercut banks = 5 -20 %
	Boulders = 8 -15 %
	Bubble curtain
Poor	Shallow and lacking cover
	Depth < 0.6 m (≤ 10 m wetted width stream)
	Depth < 0.6 m (>10 m wetted width stream)
	Criteria Conditions:
	≤ 1 piece LWD
	Undercut banks < 5 %
	Boulders < 8 %

Key:
% – percent
= – equal to
≤ - less than or equal to
≥ – greater than or equal to
< – less than
> – greater than
LWD – large woody debris
m – meters

Sources of Existing Habitat Information and Data

To the extent practical, data proposed for use in this assessment will be extracted and compiled from existing reports and datasets, other relevant available information, and available aerial photography.

To date, existing information with relevance to aquatic habitat assessment for the McCloud and Sacramento rivers above Shasta Dam has been obtained and cataloged from the following available sources:

1) Regional Project Libraries

i. Reclamation – Shasta Lake Water Resources Investigation

ii. River Exchange – Upper Sacramento River Watershed Assessment

iii. Nestle Waters – Squaw Valley Creek Investigations

2) Reclamation – Shasta Fish Passage Evaluation literature library and data files

3) FERC Project No. 2106 - McCloud-Pit Hydroelectric Project relicensing website

4) California Department of Fish and Wildlife document library (website)

5) Anadromous Fish Restoration Program (website)

6) National Marine Fisheries Service – Southwest Region (website)

7) The McCloud Coordinated Resource Management Plan work group website

8) Shasta-Trinity National Forest – met with resources staff to obtain available habitat survey data sets.

Source documents and data files have been cataloged using an EndNote® library. EndNote is a software tool for publishing and managing bibliographies, citations and references on the Windows desktop. A discrete set of data fields and data definitions form the framework of this database allowing easy searches for specific habitat related information sources and quick identification of the period of record and river basin associated with the information. Library files will be exported to Excel databases for ease of use and distribution on Reclamation's Shasta Dam Fish Passage Evaluation web site. The master project library will be maintained and updated periodically during the course of the habitat assessment.

To date, 146 documents, which include 13 data files and three GIS files have been obtained, cataloged and reviewed. Table 6 provides a brief breakdown of the numbers of sources and types of potentially useful habitat information contained in them. A content analysis of the source documents was performed and summaries of the available information and potential uses and limitations of these data for the Sacramento and McCloud rivers are shown in Tables 7 and 8. A complete bibliographic listing of the existing information sources and content analysis matrices are provided in Appendices C and D.

There are a number of particularly relevant existing information sources for use in this habitat assessment including, but not limited to:

1) Thomas R. Payne and Associates (1992) – provides a basic channel geomorphic unit inventory, with some characterization of condition, along 38 miles of the upper Sacramento River from Shasta Lake to Box Canyon Dam. This was followed up in 1997 after significant, sediment mobilizing storm events to document changes in fluvial habitat patterns.

2) U.S. Forest Service, California Department of Fish and Game, and The Nature Conservancy for the McCloud CRMP (2001) – provides a USFS Level II habitat inventory along 25 miles of lower McCloud River from Shasta Lake to McCloud Dam. This was followed up by Pacific Gas and Electric Company in 2006 to confirm applicability for physical habitat modeling as part of McCloud-Pit Hydroelectric Project relicensing study, at which time it was deemed to be similar to conditions in 2006.

3) U.S. Geological Survey (published data files on long-term stream gage and water temperature records for Sacramento and McCloud rivers near their confluences with Shasta Lake) – provide nearly continuous stream flow and water temperature records for varying periods of record reflective of conditions in the lowest reaches of the study area for these rivers.

4) California Department of Water Resources water quality library (unpublished data files) – provides various water quality and water temperature data over varying periods of record along the upper Sacramento River and near Shasta Lake on the McCloud River.

5) Reclamation, 2010 to present (unpublished data files) – provides nearly continuous thermograph records at 9 mainstem stations and on Soda Creek (a tributary) during this period.

6) California Department of Fish and Wildlife, 1990 to present (published several reports) – provide fish species composition and population abundance data along entire upper Sacramento River and select tributaries.

7) Thomas R. Payne and Associates (1993) – provides salmonid spawning habitat and distribution survey data for upper Sacramento River from Box Canyon Dam to below Big Canyon Creek confluence.

8) Pacific Gas & Electric Company (2009) – provides salmonid spawning habitat distribution surveys during 2006 and 2007 for McCloud-Pit Hydroelectric Project relicensing studies.

9) Pacific Gas & Electric Company (2011) – provides flow-habitat relationship modeling for McCloud-Pit Hydroelectric Project relicensing studies, including PHABSIM analyses for Chinook salmon and steelhead in response to State Water Board request as part of Clean Water Act Section 401 water quality certification California Environmental Quality Act analysis.

10) Hanson et al. (1940) – provides results of U.S. Bureau of Fisheries' Shasta Fish Salvage Study surveys of salmon spawning grounds conducted as part of pre-construction study of salmon populations throughout Central Valley rivers, including upstream of the Shasta Dam site.

Several additional potential sources of existing data were brought to our attention during a public workshop held on August 27, 2013 at Lakehead, California, which will be obtained, added to the information source library, and reviewed and analyzed as part of the habitat assessment. Notably, the California Department of Water Resources, California Department of Fish and Wildlife, Pacific Gas and Electric Company, and Roseburg Forest Products Company each offered access to detailed data sets on relevant water quality, habitat, and fish spawning distribution data that were otherwise only available in summary form in existing reports.

Table 6. Numbers of Source Documents Obtained and Evaluated to Date for the Shasta Dam Fish Passage Evaluation – Habitat Assessment

River System	Aquatic Environment			Physical Habitat						Biotic	
	Hydrology	Water Quality	Water Temperature	Barriers	Holding Habitat	Spawning Habitat	Rearing Habitat	Riparian Habitat	Geomorphic[a]	Fish	Other
Sacramento	5	12	9	3	1	2[a]	1	0	4	14	10
McCloud	8	21	15	3	6	17	10	4	5	19	8

Table 7. Summary of Available Information on Habitat Conditions for the Upper Sacramento River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Geospatial Information	Habitat Typing & Inventories	Channel unit inventory (CGUs, lengths, widths, longitudinal profile)	Geomorphic channel survey data including individual channel unit lengths (not widths) are available for the Sacramento River between Box Canyon Dam and Shasta Lake (TRPA 1992; Allen and Gast 2005). Localized channel inventory data are available at four stations (Stations: Near Dunsmuir, Castella, Sims Flat and Clarks Gulch) surveyed by Weaver and Mehalick (2008) that include unit lengths/widths. Geomorphic channel inventories, or summaries of inventories, are available for a number of upper Sacramento River tributaries but they are generally limited in their spatial coverage and level of detail (Miller et al. 1996). See entry below regarding gradient for longitudinal profile information.	A comprehensive channel map was completed in 1991 and resurveyed in 1997 after a large flood. The extent of contemporary applicability is somewhat uncertain. Other mainstem and tributary coverage is limited, incomplete, or missing.	At a minimum, data may require verification or augmentation. Need to obtain appendices of Miller et al. (1996) to determine if additional information on tributary streams is required. Some field verification of representative reaches will likely be required.
	Barriers	Natural (complete or partial)	No focused surveys for natural barriers in the Sacramento River or its tributaries was identified; however, none are noted in available habitat surveys. Gradient barriers were analyzed as part of the WA to identify potentially fish bearing stream reaches using NetMap.	Although no complete barriers are reported for the upper Sacramento River, historic reports of Mear's Falls as upstream limit of salmon spawning (Hanson et al. 1940).	Field survey or verification of mainstem features like Mears Falls and those in or near the mouths of tributary streams may be required.
		Culverts (*complete or partial*)	Study of I-5 culverts was conducted in 1994. The 2000 Fishery Management Plan discusses some specific structures constructed to help with fish passage. California Fish Passage Assessment Database has recent entries for culverts surveyed by Caltrans in 2009.	The 2000 Management Plan (CDFG 2000) suggests Caltrans was developing plans to construct additional ladders. Reference to a recent study regarding fish passage at crossings along the Rails-to-Trails project section has been identified but not obtained. Fish passage assessment database may not contain all existing data available.	Focused field surveys may be needed, particularly for tributary streams.
	Access Locations	Access	Map and aerial coverage along with other recent surveys provide contemporary information on access.	Existing map data are generally suitable for this purpose; however some uncertainty may remain for obscure sites.	Additional detail could be gleaned from Cantara spill studies/reports.

Table 7. Summary of Available Information on Habitat Conditions for the Upper Sacramento River to Inform the Planning of a Pilot-level Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
	Infrastructure	Dams and diversions	Basic information available for Box Canyon Dam. No other known dams/diversions identified in WA.	Only minor uncertainty about whether other small unscreened diversions exist.	May need to examine water right permit records to confirm.
		Stormwater discharge points	No information identified.	No data on any transportation, industrial, or municipal stormwater discharge was readily available; uncertain impacts.	Contact CV Regional Board to confirm whether stormwater runoff issues are important in reach.
		Wastewater effluent	Dischargers identified in WA and individual NPDES Permits are available for these discharges; however, no actual water quality data have been obtained.	Discharge limits and permits are available, but not monitoring data.	Contact CV Regional Board to confirm whether stormwater runoff issues are important in reach.
		Roads and bridges	GIS data sets for roads at various resolutions available and obtained. Complete spatial coverage.	Bridges and/or stream crossings not specifically identified.	Bridges and/or stream crossings would need to be identified using GIS, other data sets, or field verification.
		Stream gages	GIS data available for existing gage locations and existing reports document the location of stream gages in the watershed.	None	None
		Railroad bed and track	GIS data available but have not yet been acquired.		GIS data file will need to be acquired.
Geospatial Information	Spawning, Egg Incubation, and Emergence Criteria	Flow regime	Stream flow data for the Sacramento River at Delta (USGS 11342000) is complete from 1944 to 2013. Stream discharge data for points upstream of the Delta gage are limited to flows at Mt. Shasta between 1959 and 1987 and at Castella from 1910-1923. Flow release data from Box Canyon Dam are available for 2012; it is assumed that flows there are otherwise set to minimum base flows during most months. River stage data are available for the Sacramento River at Delta from 2000 to the present.	Stream flow data are limited for reaches between Box Canyon Dam and the Sacramento River at Delta.	Flow record is sufficient for lower study reach. Confirm availability of annual flow records for Box Canyon Dam.
		Water temperature	Continuous water temperature data are available for the Sacramento River at Delta from 1989-2013. Daily water temperature data are available for 9 Reclamation sites between Box Canyon Dam and Shasta Lake for 2011 and 2012. Other data are incomplete (spot mmts, incomplete records, etc.).	Temperature records for the upper river reaches is limited to only two years, but reflects current hydrology.	Temperature record is Update data for the 9 Reclamation temperature data loggers to expand record and examine longitudinal variability.
		Gradient	Gradient profiles computed from the NHD and NED (10-m DEM) are completed and available.	Gradients computed from the NED-DEM and NHD may provide reasonable representation of landscape-scale gradient, but is limited by the accuracy and resolution of elevation data used.	Field verification of representative reach gradients and steep channel features may be required.
		Channel confinement ($Width_{valley}$:$Width_{BF}$) Entrenchment ($Width_{flood}$:$Width_{BF}$)	No previous compilation of channel confinement was identified. "Channel confinement" as floodplain width:channel width was used to perform watershed modeling using NetMap for the Upper Sacramento River WA, but report provides only summarized metrics.	Reported channel confinement values are more properly termed channel entrenchment and provided only as summaries; no reach specific data.	Field measurement or verification of representative reach channel confinement and entrenchment may be required.
		Channel width (base flow, OHW, BF)	The habitat mapping surveys include reach wide mean wetted widths for entire study area. Wetted channel width data are reported for recent fish surveys (Weaver & Mehalick 2008) at summer base flow. Stations were located near Dunsmuir, Castella, Sims Flat and Clarks Gulch.	Available channel widths are limited to summarized average wetted widths at base flow.	Field measurement or verification of representative channel unit widths may be required.

Table 7. Summary of Available Information on Habitat Conditions for the Upper Sacramento River to Inform the Planning of a Pilot-level Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
		Channel depth (base flow, OHW, BF)	No information on this parameter identified.	No available data.	Field measurement of representative channel unit depths may be required.
		Substrate (D_{50}, dominant/ subdominant, Fines (%), Gravel (%), Cobble (%), D_{50})	Bed composition data are limited to reconnaissance level narrative observations. Particle size distribution data for tributareis are referred to in Miller et al. (1996), but the data appendices are missing.	No specific metric data for the concentrations of fines, availability or distribution of gravels, cobble/boulders.	Field measurement of representative channel bed composition may be required.
		Spawning gravel area (base flow, OHW)	Spawning gravel area data for the Sacramento River is limited to reconnaissance-level localized narrative observations, mostly upstream of Cantara Loop. Data are referred to in Miller et al. (1996) for tributaries, but the data appendices are missing.	No specific metric data for the distribution of suitable spawning gravel is available for the entire study reach.	Field measurement of distribution of spawning habitat along representative reaches may be required.
		Pool *Fq* (with tailouts)	Pool frequency data are available in TRPA (1992) and Allen and Gast (2005) from Box Canyon Dam-Shasta Lake. Localized pool area available for four stations surveyed in Weaver and Mehalick (2008). Stations were located near Dunsmuir, Castella, Sims Flat and Clarks Gulch.	While pool frequencies are available the characteristics are not sufficient to fully determine those associated with tailouts or proximity to spawning areas.	Field survey or verification of pool characteristics in representative reaches may be required.
Habitat Parameters	Spawning, Egg Incubation, and Emergence Criteria	Pool width	Pool width data are included as notes in geomorphic channel unit and fishery surveys performed during the mid-1990's; however no systematic measurements are provided.	No systematic pool width data are available in habitat surveys, to date.	Field measurement of pool widths in representative reaches may be required.
		Pool depth (average, maximum)	Pool depth data are included as notes in geomorphic channel unit and fishery surveys performed during the mid-1990's; however no systematic measurements are provided.	No systematic pool depth data are available in habitat surveys, to date.	Field measurement of pool depths in representative reaches may be required.
		Residual pool depth	No information identified.	No data available	Field measurement of residual pool depths in representative reaches may be required.
		Pool-spawn gravel proximity	No information identified.	No data available	Field measurement of pool proximity to spawning gravel in representative reaches may be required.
	Rearing criteria	Flow regime	Stream flow data for the Sacramento River at Delta (USGS 11342000) is complete from 1944-2013. Stream discharge data for points upstream of the Delta gage are limited to flows at Mt. Shasta between 1959 and 1987 and at Castella from 1910-1923. Flow release data from Box Canyon Dam are available for 2012; it is assumed that flows there are otherwise set to minimum base flows during most months. River stage data are available for the Sacramento River at Delta from 2000 to the present.	Stream flow data are limited for reaches between Box Canyon Dam and the Sacramento River at Delta.	Confirm availability of annual flow records for Box Canyon Dam.
		Water temperature	Continuous water temperature data are available for the Sacramento River at Delta from 1989-2013. Daily water temperature data are available for 9 Reclamation sites between Box Canyon Dam and Shasta Lake for 2011 and 2012. Other data are incomplete (spot mmts, incomplete records, etc.).	Temperature records for the upper river reaches is limited to only two years, but reflects current hydrology.	Update data for the 9 Reclamation temperature data loggers to expand record and examine longitudinal variability.

Table 7. Summary of Available Information on Habitat Conditions for the Upper Sacramento River to Inform the Planning of a Pilot-level Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
		Gradient	Gradient profiles computed from the NHD and NED (10-m DEM) are completed and available.	Gradients computed from the NED-DEM and NHD may provide reasonable representation of landscape-scale gradient, but is limited by the accuracy and resolution of elevation data used.	Field verification of representative reach gradients and steep channel features may be required.
		Channel confinement ($Width_{valley}$:$Width_{BF}$) Entrenchment ($Width_{flood}$:$Width_{BF}$)	No previous compilation of channel confinement was identified. "Channel confinement" as floodplain width:channel width was used to perform watershed modeling using NetMap for the Upper Sacramento River WA, but report provides only summarized metrics.	Reported channel confinement values are more properly termed channel entrenchment and provided only as summaries; no reach specific data.	Field verification of representative reach channel confinement and entrenchment may be required.
		Substrate (D_{50}, dominant/ subdominant, % fines (productivity), % gravel (productivity & cover), % cobble/boulder (cover))	Bed composition data are limited to reconnaissance level narrative observations. Particle size distribution data for tributaries are referred to in Miller et al. (1996), but the data appendices are missing.	No specific metric data for the concentrations of fines, availability or distribution of gravels, cobble/boulders.	Field measurement of representative channel bed composition may be required.
Habitat Parameters	Rearing criteria	Pool *Fq* / area	Pool frequency data are available in TRPA (1992) and Allen and Gast (2005) from Box Canyon Dam-Shasta Lake. Localized pool area available for four stations surveyed in Weaver and Mehalick (2008). Stations were located near Dunsmuir, Castella, Sims Flat and Clarks Gulch.	Pool areas could be computed using average widths broken out by unit/reach. Data are 21 years old and at least one significant flow event has occurred since original surveys.	Field measurement or verification of pool frequencies and channel widths in representative reaches may be required.
		Pool complexity (depth relative to width, boulder, turbulence, LWD, undercut banks)	Data are limited to notes in TRPA (1992) geomorphic channel unit and fishery surveys performed during the early- to mid-1990's.	No systematic surveys or data records were found for elements of pool complexity.	Field measurements or verification of pool complexity elements in representative reaches may be required.
		Overhead cover (%)	No information identified.	No data available.	Field measurements or verification of overhead cover in representative reaches may be required.
		Dominant cover type	No information identified.	No data available.	Field measurements or verification of dominant cover in representative reaches may be required.
		Total cover	No information identified.	No data available.	Field measurements or verification of available cover in representative reaches may be required.
		LWD *Fq* (*by size classes*)	Potential for large woody debris accumulation and types for a portion of the upper watershed were modeled with NetMap and summarized in the upper Sacramento River WA.	Modeled LWD volume and distributions were only summarized in the WA; no reach specific information provided.	Field measurements or verification of LWD distributions in representative reaches may be required.

Table 7. Summary of Available Information on Habitat Conditions for the Upper Sacramento River to Inform the Planning of a Pilot-level Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
		Riparian vegetation (percent of bank length, width)	No sources of these specific metrics are readily available.	Some level of analysis may be performed using GIS data files (e.g., USFS RSL Veg Map, FloodPlain, FloodPlain Veg, etc.)	Field measurements or verification of riparian vegetation coverage in representative reaches may be required.
		Stranding risk/types	No information identified.	Some level of analysis may be performed using GIS data files	Field measurements or verification of stranding features in representative reaches may be required.

Key:

% – percent
BF – bankfull
CDFG – California Department of Fish and Game
CGU – channel geomorphic unit
CV – Central Valley
D50 – median diameter of a grain-size distribution
DEM – digital elevation model
Fq – frequency
GIS – geographic information system
I-5 – Interstate Highway 5
LWD – large woody debris
mmts – measurements
NED – National Elevation Database
NHD – National Hydrologic Database
NPDES – National Pollutant Discharge Elimination System
OHW – ordinary high water
TRPA – Thomas R. Payne and Associates
USFS RSL – US Forest Service's Redwood Science Laboratory
USGS – US Geological Survey

Table 8. Summary of Available Information on Habitat Conditions for the McCloud River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Geospatial Information	Habitat Typing & Inventories	Channel unit inventory (CGUs, lengths, widths, longitudinal profile)	A channel unit inventory that includes unit lengths, widths, dominant substrate and cover is available for the McCloud River between McCloud Dam and Shasta Dam (McCloud CRMP 2001). CGUs are also available for study sites used in relicensing studies (9 sites between McCloud Dam and Shasta Lake for stream fish, 6 BMI sites and 5 intensive channel morphology sites between McCloud Dam and Squaw Valley Creek, and 10 instream flow study sites between McCloud Dam and Shasta Lake). CGU coverage available for 4 sites on Squaw Valley Creek. See gradient entry below for details on longitudinal profile.	Habitat unit inventory complete for entire study reach from McCloud Dam to Shasta Lake, with confirmed functional similarity in 2007 by PG&E. Large wildfires in watershed in 2012 could affect validity in future; no channel unit data above McCloud Dam.	Obtain USFS GIS data files if available. Validation of habitat unit designations comparable to those described in PG&E 2007 may be required.
	Barriers	Natural (*complete or partial*)	No systematic survey of fish passage impediments were identified; however, none are noted in recent habitat inventories. A brief 1960 memo identifies a rock-reef barrier near Chatterdown Creek; NSR (2008) suggests partial fish passage barrier at Tuna Creek, primarily for warmwater fishes ascending the river from Shasta Lake. Trout migration studies provide insight into migration between Shasta Lake the McCloud River Preserve	Some uncertainty concerning current status of channel and barrier formation following 2012 wildfires and subsequent sediment inputs.	Additional map and aerial photo interpretation and focused field surveys for passage impediments, both in the McCloud and its tributaries, may be required.
		Culverts (*complete or partial*)	Fish passage data for man-made structures is limited to global summaries in watershed assessments, management plans, PG&Es Pre Application Document, etc. The CDFG fish passage assessment database covers the McCloud watershed and the only data point is for McCloud Dam.	Fish passage assessment database may not contain all existing data available. Lacking detail on fish passage on tributary streams.	Additional map and aerial photo interpretation and focused field survey for road crossings passage impediments, both in the McCloud and its tributaries, may be required.
	Access Locations	Access	Map and aerial coverage along with other recent surveys provide contemporary information on access.	Existing map data are generally suitable for this purpose; however some uncertainty may remain for obscure sites.	Examine USFS roads layer and County road layers using GIS.
	Infrastructure	Dams and diversions	McCloud-Pit Hydroelectric project documents (PAD, License Application, & Technical Memos provide detail on project dams and diversions in the McCloud Watershed between McCloud Dam and Shasta Lake and for the wider hydroelectric project-area.	None. FERC application is comprehensive	No additional data needed.
		Stormwater discharge points	No information identified.	Little transportation and no municipal development in the study area, along with no industrial development other than forestry,	Contact CV Regional Board to confirm whether stormwater runoff issues are important in reach.
		Wastewater effluent	No information identified.	No municipal or industrial developed wastewater treatment in reach.	None.
		Roads and bridges	GIS data sets for roads at various resolutions available and obtained from Shasta and Siskiyou counties. Complete spatial coverage.	Bridges and/or stream crossings not specifically identified.	Bridges and/or stream crossings would need to be identified using GIS, other data sets, or field
		Stream gages	Available GIS data sets and existing reports document the location of primary stream gages in the watershed. Relicensing studies provide extensive information on watershed hydrology and hydroelectric infrastructure	None. FERC application is comprehensive.	None.
		Railroad bed and track	No information identified.	No rail transportation known in study reach.	None.

Table 8. Summary of Available Information on Habitat Conditions for the McCloud River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Geospatial Information	Infrastructure	Flow regime	Stream flow data (mean daily) for the McCloud River are available for the past 30 years at four locations in the McCloud River ranging from McCloud Dam to Shasta Lake. River stage elevation data limited to last 3-5 years at MSS and MCD. Some flow records date back to the 1930s. Tributary stream flow data are limited to a few small creeks within the McCloud River preserve collected during the late-1980s and recent data for Squaw Valley Creek. Includes report of unimpaired and regulated flow regimes for the McCloud River (TM-46).	Temporal coverage in tributary streams is limited, except for recent measurements in Squaw Valley Creek.	Flow record is sufficient for mainstem; limited in tributaries, may need to use rational hydrologic estimation for tributary flow regimes, if necessary.
		Water temperature	Daily records available for the above Shasta Lake for 1996- 2009 and the McCloud River Preserve for 1990-2010. Hourly data are available above Shasta for 1989-2010 and McCloud River Preserve for 1996-2010. Median daily records are available from 1874-1883 for historical context (Baird Hatchery). 15-minute records are available for 14-riverine stations between McCloud Dam and Shasta Lake for 2007 and 2008 along with a complete water temperature modeling report (TM-26). Seasonal data are available for Ladybug and Bald Mountain creeks during mid-1980s and continuous records are available for 5 stations on Squaw Valley Creek between McCloud and the McCloud River confluence and on the upper river at Dakin Dam (above Big Springs) for 2008- 2010 (NSR 2011).	Records are sufficient for mainstem; but limited for tributary streams, except for recent records for Squaw Valley Creek.	Water temperature record is sufficient for mainstem; limited for tributary streams.
		Gradient	Gradient profiles computed from the NHD and NED (10-m DEM) are available. Reach gradient data are available for the McCloud between McCloud Dam and just US of Squaw Valley Creek (TM-68) and site specific measurements for fish pop/instream flow modeling sites (8-10 sites) concentrated in the upper river (US Squaw Valley Creek) and lower river (DS Tuna Creek).	Field verified field measurements limited in the mid-section of the McCloud River between unnamed tributaries downstream of Ladybug Creek and Tuna Creek.	Field verification of representative reach gradients and steep channel features may be required, but likely only needed in the mid-reach of the study area.
		Channel confinement ($Width_{valley}$:$Width_{BF}$) Entrenchment ($Width_{flood}$:$Width_{BF}$)	Channel confinement descriptions and data (map/field verified data) are available for the upper McCloud River between McCloud Dam and Squaw Valley Creek (TMs-65 & 68). Otherwise, spatial coverage is limited.	Data coverage limited to the upper McCloud River (US of Squaw Valley Creek).	Field verification of representative reach channel confinement may be required, but likely only needed in the mid and lower reaches of the study area.
		Channel width (base flow, OHW, BF)	Base flow channel width data are available for the entire reach from McCloud Dam-Shasta Lake (2001 CRMP). Technical memos for BMI (5 sites McCloud Dam-Squaw Valley Creek) and stream fish (9 sites McCloud Dam-Shasta Lake) provide localized channel width data. Width data for 10 sites between McCloud Dam and Shasta Lake and channel morphology studies between McCloud Dam and Squaw Valley Creek provided in instream flow TMs.	Detailed channel width data are limited for mid-river reaches.	Field verification of channel widths in representative reaches may be required, especially in the mid and lower reaches of the study area.

Table 8. Summary of Available Information on Habitat Conditions for the McCloud River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Geospatial Information	Spawning, Egg Incubation, and Emergence Criteria	Channel depth (base flow, OHW, BF)	Technical memos for BMI (5 sites McCloud Dam-Squaw Valley Creek) and stream fish (9 sites McCloud Dam-Shasta Lake) provide localized base flow channel depth data. Depth data for the 10 sites between McCloud Dam and Shasta Lake and channel morphology studies between McCloud Dam and Squaw Valley Creek provided in instream flow TMs.	Detailed channel depth data are limited for mid-river reaches.	Field verification of channel widths in representative reaches may be required, especially in the mid-and lower reaches of the study area.
		Substrate (dominant/ subdominant, Fines (%), Gravel (%), Cobble (%), D_{50})	Detailed substrate information are available for the 5 intensive study sites on the McCloud River between McCloud Dam and Squaw Valley Creek (D_{50}, facies, particle size dist., etc.) (TM-68). TM-35 provides pebble count data for 5-sites on McCloud River between the dam and Squaw Valley Creek (Squaw Valley Creek) and 2 sites on Squaw Valley Creek. TM-18 provides substrate composition at 9 sites between the McCloud Dam and Shasta Lake and TM-65 provides composition in riparian areas at 90 plot stations. TM-80 provides detail on salmonid spawning gravel including D_{50} and D_{84} for the 10 instream flow study sites between McCloud Dam and Shasta Lake. McBain (1989) provides a summary of spawning gravel size distributions, but data are lacking in electronic copy. Substrate data are available (pebble counts, dominant/subdominant) for upper Squaw Valley Creek; substrate data for other tributaries are otherwise limited in geographic coverage and detail. Primary and secondary substrates are provided with habitat type inventory for study reach (CRMP 2001).	Basic dominant/subdominant characterization available for entire study area. Level of detail for other substrate metrics varies and is not the same for all reaches.	Field measurement or verification of bed substrate characteristics in representative reaches may be required, especially in the mid-and lower reaches of the study area.
		Spawning gravel area (base flow, OHW)	Spawning gravel area and quality rating (including redd surveys) are available for the 9 stream fish survey sites between McCloud Dam and Shasta Lake along with the 10 instream flow study sites. These surveys looked at gravel deposits located up to levels associated with a 1.5 year flow event. Continuous patch size data are available for the reach between McCloud Dam and RM 18. This reach includes information on gravel deposits and storage outside the base flow channel. Weighted usable spawning habitat curves provided by TM-81. Spawning gravel area and quality for the McCloud River and tributaries immediately upstream of Shasta Lake are also available (NSR 2008).	Basic spawning gravel characterization available for a large portion of the study area, including a PHABSIM estimate of usable spawning area for above and below Squaw Valley Creek. Level of detail for spawning gravel area varies among reaches and is least certain in the mid-reach of study area.	The PG&E relicensing study provides considerable analysis for estimating suitable spawning areas above and below Squaw Valley Creek, but does not provide for finer spatial distribution of spawning areas than this simple division. Further analysis of map and aerial photo interpretation, along with focused field surveys may be required to enhance understanding of the spatial distribution of spawning habitat.
		Pool *Fq* (with tailouts)	Pool frequency and area data are available for the entire reach from McCloud Dam-Shasta Lake (2001 CRMP).	While pool frequencies are available, the characteristics are not sufficient to fully determine those associated with tailouts or proximity to spawning areas.	Field survey or verification of pool characteristics in representative reaches may be required.
		Pool width	Pool width data are available for the entire reach from McCloud Dam-Shasta Lake (2001 CRMP). Technical memos for BMI (5 sites McCloud Dam-Squaw Valley Creek) and fish population (9 sites McCloud Dam-Shasta Lake) provide localized data. Additional area data are available in the instream flow TM-s for the 10 sites between McCloud Dam and Shasta Lake.	Pool widths are summarized in the CRMP (2001) report and measurements were limited for mid-river reaches for PG&E studies; some uncertainty concerning current status of pool condition following 2012 wildfires and subsequent sediment inputs.	Need to request and obtain USFS dataset for CRMP (2001), if available. Some focused field measurement of pool widths in representative reaches may be required.

Table 8. Summary of Available Information on Habitat Conditions for the McCloud River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs	Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Habitat Parameters	Pool depth (average, maximum)	Pool depth data are available for each of the 9 stream fish population sites on the McCloud River between McCloud Dam and Shasta Lake (TM-18); raw data included. Transect depths were used as model inputs for instream flow studies; transect pool depth data were not available in report/appendices.	Pool depth data is limited to the 9 fish study sites, primarily concentrated upstream of Squaw Valley Creek and downstream of Tuna Creek. Measurements for the mid-reach are limited. Some uncertainty concerning current status of pool depths following 2012 wildfires and subsequent sediment inputs.	Some focused field measurement of pool widths in representative reaches with limited data may be required.
	Residual pool depth	No information identified.	No data available.	Field measurement of residual pool depths in some representative reaches may be required.
	Pool-spawn gravel proximity	No information identified.	No specific characterization of this parameter was found in the available data; however, some re-evaluation of existing data may be possible to extract this information.	Some re-evaluation of McCloud CRMP (2001) habitat inventory and PG&E spawning gravel surveys, along with some focused field measurement of pool widths in representative reaches may be required.
	Flow regime	Stream flow data (mean daily) for the McCloud River are available for the past 30 years at four locations in the McCloud River ranging from McCloud Dam to Shasta Lake. River stage elevation data limited to last 3-5 years at MSS and MCD. Some flow records date back to the 1930s. Tributary stream flow data are limited to a few small creeks within the McCloud River preserve collected during the late- 1980s and recent data for Squaw Valley Creek. Includes report of unimpaired and regulated flow regimes for the McCloud River (TM-46).	Temporal coverage in tributary streams is limited, except for recent measurements in Squaw Valley Creek.	Flow record is sufficient for mainstem; limited in tributaries, may need to use rational hydrologic estimation for tributary flow regimes, if necessary.
	Water temperature	Daily records available for the above Shasta Lake for 1996- 2009 and the McCloud River Preserve for 1990-2010. Hourly data are available above Shasta for 1989-2010 and McCloud River Preserve for 1996-2010. Median daily records are available from 1874-1883 for historical context (Baird Hatchery). 15-minute records are available for 14-riverine stations between McCloud Dam and Shasta Lake for 2007 and 2008 along with a complete water temperature modeling report (TM-26). Seasonal data are available for Ladybug and Bald Mountain creeks during mid-1980s and continuous records are available for 5 stations on Squaw Valley Creek between McCloud and the McCloud River confluence and on the upper river at Dakin Dam (above Big Springs) for 2008- 2010 (NSR 2011).	Records are sufficient for mainstem; but limited for tributary streams, except for recent records for Squaw Valley Creek.	Water temperature record is sufficient for mainstem; limited for tributary streams.
	Gradient	Gradient profiles computed from the NHD and NED (10-m DEM) are available. Reach gradient data are available for the McCloud between McCloud Dam and just US of Squaw Valley Creek (TM-68) and site specific measurements for fish pop/instream flow modeling sites (8-10 sites) concentrated in the upper river (US Squaw Valley Creek) and lower river (DS Tuna Creek).	Field verified field measurements limited in the mid-section of the McCloud River between unnamed tributaries downstream of Ladybug Creek and Tuna Creek.	Field verification of representative reach gradients and steep channel features may be required, but likely only needed in the mid-reach of the study area.
	Channel confinement ($Width_{valley}$:$Width_{BF}$) Entrenchment ($Width_{flood}$:$Width_{BF}$)	Channel confinement descriptions and data (map/field verified data) are available for the upper McCloud River between McCloud Dam and Squaw Valley Creek (TM-s 65 & 68). Otherwise, spatial coverage is limited.	Data coverage limited to the upper McCloud River (US of Squaw Valley Creek).	Field verification of representative reach channel confinement may be required, but likely only needed in the mid-and lower reaches of the study area.

Table 8. Summary of Available Information on Habitat Conditions for the McCloud River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Habitat Parameters	**Rearing Criteria**	Substrate (D_{50}, dominant/ subdominant, fines (%) (productivity), gravel (%) (productivity and cover), cobble/boulder (%) (cover))	Detailed substrate information are available for the 5 intensive study sites on the McCloud River between McCloud Dam and Squaw Valley Creek (D_{50}, facies, particle size dist., etc.) (TM-68). TM-35 provides pebble count data for 5-sites on McCloud River between the dam and Squaw Valley Creek (Squaw Valley Creek) and 2 sites on Squaw Valley Creek. TM-18 provides substrate composition at 9 sites between the McCloud Dam and Shasta Lake and TM-65 provides composition in riparian areas at 90 plot stations. TM-80 provides detail on salmonid spawning gravel including D_{50} and D_{84} for the 10 instream flow study sites between McCloud Dam and Shasta Lake. McBain (1989) provides a summary of spawning gravel size distributions, but data are lacking in electronic copy. Substrate data are available (pebble counts, dominant/subdominant) for upper Squaw Valley Creek; substrate data for other tributaries are otherwise limited in geographic coverage and detail. Primary and secondary substrates are provided with habitat type inventory for study reach (CRMP 2001).	Basic dominant/subdominant characterization available for entire study area. Level of detail for other substrate metrics varies and is not the same for all reaches.	Field measurement or verification of bed substrate characteristics in representative reaches may be required, especially in the mid-and lower reaches of the study area.
		Pool *Fq* / area	Pool frequency and area data are available for the entire reach from McCloud Dam-Shasta Lake (2001 CRMP).	Pool frequencies and area computations are available from the McCloud CRMP (2001) survey report; some uncertainty concerning current status of pool widths and depths following 2012 wildfires and subsequent sediment inputs.	Field survey or verification of pool characteristics in representative reaches may be required.
		Pool complexity (depth relative to width, boulder, turbulence, LWD, undercut banks)	Pool complexity data are available for fish population study sites (9 between McCloud Dam and Shasta Lake), BMI study sites (6 between McCloud Dam and Squaw Valley Creek), and for instream flow study sites (10 between McCloud Dam and Shasta Lake). Detailed information are available for 4-sites on Squaw Valley Creek, but are otherwise lacking for tributary streams.	Existing data may be sufficient for the upper and lower reaches of study area; however, it is limited for mid-river reaches and tributary streams. Some uncertainty concerning current status of pool widths and depths following 2012 wildfires and subsequent sediment inputs.	Field survey or verification of pool characteristics in some representative reaches may be required.
		Overhead cover (%)	Canopy cover are available for 6 BMI study sites between McCloud Dam and Squaw Valley Creek and multiple sites on Squaw Valley Creek.	Existing data may be sufficient for some portion of the study area; it is limited for the mid-river reaches and tributary streams.	Field survey or verification of cover characteristics in some representative reaches may be required.
		Dominant cover type	Dominant cover type is available for fish the 9 fish population survey sites between McCloud Dam and Shasta Lake (TM-18). Shelter value ratings are available for geomorphic channel units surveyed from McCloud Dam-Shasta Lake (CRMP 2001).	Existing data may be sufficient for some portion of the study area; it is limited for the mid-river reaches and tributary streams.	Field survey or verification of cover characteristics in some representative reaches may be required.
		Total cover	Shelter value ratings are available for geomorphic channel units surveyed from McCloud Dam-Shasta Lake (CRMP 2001). Data from TMs could augment data for specific study sites (overhead cover/dominant cover types identified above).	Existing data may not meet requirements for defining total cover values. Detailed data are limited for mid-river reaches and tributary streams.	Field survey or verification of overall cover characteristics in some representative reaches may be required.
		LWD Fq (*by size classes*)	LWD management plan describes the function of LWD in the McCloud River and options for placement of LWD. Does not include inventory data, but discusses how LWD currently functions in the river system.	No LWD inventory data in record.	Field measurements or verification of LWD distributions in representative reaches may be required.

Table 8. Summary of Available Information on Habitat Conditions for the McCloud River to Inform the Planning of a Pilot-level Chinook Salmon Reintroduction Study Above Shasta Dam (contd.)

Information Needs		Parameters	Spatial/Temporal Coverage	Data Limitations or Qualifications	Additional Data Needed
Habitat Parameters	**Rearing Criteria**	Riparian vegetation (percent of bank length, width)	Detailed riparian vegetation data including coverage and widths are available for the McCloud River between McCloud Dam and just upstream of Squaw Valley Creek (TM-65).	Data are sufficient for the upper river, but lacking for the mid- and lower reaches.	Field surveys and measurement of riparian vegetation conditions and coverage in representative reaches of the mid and lower reaches may be required.
		Stranding risk/types	No information identified.	Some level of analysis may be performed using GIS data files.	Field measurements or verification of stranding features in representative reaches may be required.

Key:
% – percent
BF – bankfull
BMI – benthic macroinvertebrate
CDFG – California Department of Fish and Game
CGU – channel geomorphic unit
CRMP – Coordinated Resource Management Plan
D_{50} – median diameter of a grain-size distribution
DEM – digital elevation model
DS – downstream
FERC – Federal Energy Regulatory Commission
Fq – frequency
GIS – geographic information system
LWD – large woody debris
MCD – McCloud River gaging station below McCloud Dam
MSS – McCloud River gaging above Shasta Lake
NED – National Elevation Database
NHD – National Hydrologic Database
NPDES – National Pollutant Discharge Elimination System
OHW – ordinary high water
PAD – Preliminary Application Document
PG&E – Pacific Gas and Electric Company
PHABSIM – Physical Habitat Simulation Model
RM – river mile
TM – Technical Memoranda supporting PG&E's McCloud-Pit Project license application that are sequentially numbered
TRPA – Thomas R. Payne and Associates
US – upstream
USFS – US Forest Service
USGS – US Geological Survey

Use of Existing Data

Habitat attribute data contained in existing information sources can be of varying quality for use in this habitat assessment depending on the original objective and methods for data collection, period of record, elapsed time since data collection and rates of environmental change, and geographic coverage. Following is a summary of the status and potential use of existing information sources based on our initial content analysis.

Infrastructure

Existing state, county and local infrastructure inventory and mapping data appear adequate for the purpose of this habitat assessment and will be included in map products. Verification of the locations of stream crossings, access roads to the river, and other infrastructure will be performed using geo-referenced aerial videography to be obtained during this assessment and post-processing in GIS. Additionally, coordination with landowners is occurring as part of an associated Public/Stakeholder Outreach effort, which may develop additional opportunity for river site accesses and will be included on mapping products pending approval by individual landowners.

Hydrology and Water Temperature

Characterization of the hydrologic and water temperature conditions of the mainstem Sacramento McCloud rivers, and several of their larger tributaries can be performed with the existing data sets, which contain 3 to 10 years of contemporary data and various intervals of historic data for several locations along each river.

Graphical analysis of annual hydrographs and thermographs will be performed to characterize seasonal patterns and annual variability of each parameter. Statistical metrics will be computed to evaluate monthly mean, minimum, and maximum flows; flow durations on a monthly basis; and frequency and duration of annual peak flows for each available gaging record. Statistical metrics to be evaluated for each thermograph record include mean, maximum, and minimum daily temperatures by month; maximum weekly average temperature (MWAT) by month for May through September; and frequency analysis of exceedances of critical thermal thresholds for spawning (14 degrees Celsius (°C)) and rearing (19°C) life stages during periods of the year when these activities occur for the salmonid species targeted for reintroduction. Identification of seasonal periods and the frequency of exceedances of the thermal thresholds will be used to determine any temperature-mediated limitations on habitat suitability of specific reaches represented by thermograph stations.

Physical Habitat

Channel geomorphic unit surveys have been historically conducted in both the upper Sacramento and McCloud rivers, the Sacramento River in the 1991 and 1997 and the McCloud in 2001. Varying amounts of habitat attribute data,

mostly related to channel morphology and less so to habitat-specific features, were included with these surveys but the applicability of these data to current conditions is uncertain. The 2001 McCloud River survey was verified by Pacific Gas and Electric Company as having been reasonably applicable to the physical habitat conditions as recently as 2007 (PG&E 2007 – Technical Memorandum #4). However, significant sediment inputs to the McCloud River have been report to have occurred since 2012 as a result of heavy fall storms on exposed soils within the recent Bagley Fire, especially downstream of Claiborne Creek, which may have affected habitat conditions. No contemporary verification of the historic Sacramento River surveys has been discovered, to date.

Pacific Gas and Electric Company in 2011and 2012 also conducted habitat distribution mapping and modeling of potential spawning areas along the McCloud River from McCloud Dam to Shasta Lake for anadromous salmonids (PG&E 2012 – Technical Memoranda #80 and #81). This latter effort is highly relevant to the current habitat assessment and may provide sufficient data for mapping suitable salmon spawning habitat along the lower McCloud River; however, no comparable inventory or evaluation of spawning habitat is available upstream of McCloud Dam. Pacific Gas and Electric Company offered to provide data sets from their work at the August 27, 2013 public workshop in Lakehead.

The historic channel unit surveys will be used to provide, at the least, a historic basis for comparison with channel unit maps that will be generated using the geo-referenced videography to be obtained during this assessment. If the channel unit series to be derived from the aerial videography are comparable to the historic surveys, then the attribute data provided with historic surveys will be used to augment data collected in the current assessment.

Ecological Conditions

Existing sources of information on fish distribution and abundance and other biological resource surveys that have been conducted within the last 7 to 10 years appear to provide relevant and useful information for characterizing the potential ecological conditions related to competition, predation, and macroinvertebrate production within the study reaches.

Data Collection

To supplement the existing information on habitat conditions, geo-referenced aerial videography will be collected as part of this assessment effort, along with limited ground-level surveys at locations representative of the larger study area.

Aerial Videography

A helicopter flight service will be contracted to obtain low-altitude, slow-flight aerial videography along mainstem river channels and portions of significant

tributaries during base flow conditions. The entire length of the upper Sacramento River from Shasta Lake to Box Canyon Dam will be flown. The McCloud River will be flown in two sections, the lower section from Shasta Lake to McCloud Dam and the upper section from McCloud Lake to Lower Falls. Flights will be conducted at the lowest practical altitude, usually 100 to 200 feet above ground-level, where legal and safe, and at a ground-speed of 17 to 30 knots (15 to 25 miles per hour). A Red Hen spatial digital video recorder (sDVR) connected to a geographic positioning system (GPS) and a Sony HDR–PJ790V video camcorder will be used to simultaneously obtain aerial video images and GPS coordinates. Video files collected with the sDVR will be analyzed directly within a GIS platform using specialized extension software for habitat mapping.

To the extent possible with the level of resolution of video images, geomorphic channel units will be visually assigned to channel center line features in the GIS following the Level III habitat typing convention described in the *U.S. Forest Service Pacific Southwest Region Stream Condition Inventory Technical Guide* (Frazier et al. 2005), which is comparable to the convention used for historic surveys. Side channels and backwaters associated with centerline features will be differentiated from main channel features in the GIS using a separate attribute fields in the GIS database. For each geomorphic channel unit, habitat attributes associated with channel morphology, substrate, and cover will be determined. However, substrate characterization will be limited to determination of dominant and subdominant bed composition.

Key features associated with pools, specifically, differentiation of deep and shallow pools, pools with suitable spawning gravel on tailouts, and areal extents of potentially suitable spawning gravel patches on pool tailouts, and elsewhere, will be estimated visually from the video images and recorded in the GIS database. Areas of suitable spawning gravel on pool tailouts and riffle features will be estimated for river stages at the time of video collection (approximately base flow) and at the ordinary high water (OHW) mark. The OHW mark, in this case, is thought to represent the typical stage of study streams at flows when the winter-run Chinook salmon spawns during the spring to early-summer months. Indicators of the OHW mark will consist of a distinct demarcation of the extent of terrestrial plant establishment between the active channel and floodplain, if any, but, in no case, will extend above the bankfull elevation. Gravel areas on these channel features will be assumed to provide generally suitable spawning conditions in terms of gravel area, water depth and velocity, if gravel deposits are at least one square meter in area and would be inundated to a depth of at least 0.15 m under the targeted river stage, which will be the base flow and OHW stage flow for purposes of this assessment. If suitable spawning gravel areas (as defined in the previous sentence) occur as discontinuous deposits, or patches, within a habitat unit, the sum total of the areas of each spawning gravel patch and the number of contributing gravel patches will be recorded.

Representative Field Sites

Ground-level inspections will be conducted to verify videographic interpretations at a select number of accessible representative sites across the range of channel types and in locations where aerial videography is obscured. Surveys will include data collection for verification of video interpretations of habitat types, potential for migratory impediments created by some high-gradient riffles and cascades, bed substrate composition, type and extent of cover components, pool complexity and shelter values, and areal extent of suitable spawning gravels.

The initial basis for locating representative sites will be a hierarchical stratification of up to 10 sites in each of the Sacramento and McCloud watersheds in proportion to 1) the number of homogeneous gradient segments, and 2) number of different reach types within each gradient segment. Final site selection may be limited to publicly accessible areas, which are relatively frequent along the upper Sacramento River, but are greatly limited along the McCloud River. Cooperative agreements for access to the rivers through privately-owned lands are currently being pursued but the outcomes of these negotiations are premature for consideration in this assessment framework. Each representative site will consist of a length of stream channel equal to at least 20 average bankfull channel widths up to 1,000 meters, depending on local channel conditions, with the minimum objective to include at least one full channel meander wavelength, or two riffle-pool sequences, within the survey site.

Habitat inventory procedures to measure and collect the selected attribute data will follow procedures described by the *U.S. Forest Service Pacific Southwest Region Stream Condition Inventory Technical Guide* (Frazier et al. 2005) and the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2010). Substrate composition will be evaluated on pool tailouts and transverse bar riffles by visually estimating dominant and subdominant bed particles and using Wolman pebble counts. Pebble counts will be used to compute grain-size frequency distributions for comparison with dominant/subdominant substrate determinations. Substrate embeddedness will be visually estimated for each large gravel and cobble particle measured as the proportion of the particle height surrounded by sand and silt from 0 to 5 percent and in quartiles for greater amounts (Platts et al. 1983).

Data collected in the field at representative sites will be compared to those from videographic interpretation for each field site channel segment surveyed. Several metrics for key habitat attributes will be compared, including habitat type, dominant bed substrate, dominant cover type, large woody debris (LWD) counts, and areas of spawning gravel. The statistical distributions of these key habitat attributes for the two methods will be compared using the Hollander test, a distribution-free statistical test of the interchangeability of variables drawn from a bivariate population (Hollander and Wolfe 1973), which the

measurements from the video interpretation and field surveys may be considered.

Spawner Capacity

The number of potential spawning pairs of Chinook salmon that may be reasonably expected to be supported by a stream depends on the amount of suitable spawning habitat and area required per pair of fish (Bjornn and Reiser 1991). Suitable spawning habitat requires appropriate combinations of bed substrate size, water depth and velocity, and adjacent cover for staging, and is usually much less than the total gravel bed area in a stream. Furthermore, competitive interactions and territorial behavior among spawning salmon generally results in spatial requirements for each spawning pair exceeding that of the area occupied by an individual redd (Bjornn and Reiser 1991; Healey 1991).

Typical sizes of completed Chinook salmon redds range from 3 to 10 square meters ($m^{2)}$ and are primarily influenced by fish size (i.e., large fish build large redds) (Bell 1990; Bjornn and Reiser 1991; Kondolf et al. 2008), but can also be affected by stream channel size and habitat constituents that influence the patterns of sediment deposition on streambeds, hydraulics, and upwelling currents, such as large boulders and LWD (Kondolf et al. 2008). Campos et al. (2013) reported redd areas ranging from 0.65 to 20 m^2, with a mean of about 6 m^2 for spring, fall, and late-fall Chinook salmon in the Yuba River, California. In Clear Creek and Battle Creek, tributaries to the Sacramento River, spring-run Chinook have been reported to spawn in smaller, localized patches of gravel (M. Brown, U.S. Fish and Wildlife Service, Red Bluff, California, personal communication). The actual area required by each pair of Chinook salmon to complete redd construction and spawning includes defended space around nest sites, resulting from territorial and competitive behavior during spawning, and sufficient space to accommodate the oftentimes varying quality of spawning sites (e.g., poor or patchy substrate quality may result in a female digging more than one redd) (Baxter 1991; Bjornn and Reiser 1991; Healey 1991; Quinn 2005). The resulting area of suitable spawning habitat required for each pair of spawning Chinook salmon has been estimated to range from two to four times that of the size of a completed redd and typically ranges from about 13 m^2 for the generally smaller spring Chinook salmon to as much as 30 m^2 for fall and summer Chinook salmon (Bell 1990; Burner 1951, as cited in Bjornn and Reiser 1991; J. Hannon, U.S. Bureau of Reclamation, Sacramento, California, personal communication).

Unfortunately, no empirical data on redd size or spawning area requirements specifically for Sacramento River winter-run Chinook salmon, the target species for pilot reintroduction studies above Shasta Dam, could be found in our literature search. Even if it were, for their current restricted spawning grounds in the Sacramento River below Keswick Dam, it would not likely be directly

comparable to conditions in the upper watershed tributaries due to differences in channel size, geomorphology, and hydraulics between the lower river and its tributaries above Shasta Lake. However, it can be inferred that the spawning area requirement for winter-run Chinook salmon may likely be near the lower end of the observed range for the species, in general, because the majority of the winter run has been observed to mature and spawn at age 3 and, consequently, are typically smaller in size than fall run salmon (Hallock and Fisher 1985).

Based on the preceding considerations of redd size, territorial behavior, and habitat suitability requirements for Chinook salmon spawners and the habitat data to be compiled by this assessment, the following approach for estimating a reasonable number of salmon spawners for the purposes of the pilot reintroduction study is proposed:

Assumptions:

1) average area of winter-run Chinook salmon redd (A_{redd}) = 5 m^2;

2) average total defended space[1], A_{terr}, is equal to 4· A_{redd} = 20 m^2;

3) delineated spawning habitat areas, H (in m^2), on pool tailouts and transverse gravel bars that would include suitable water depths;

4) "gravel/cobble" (dominant/subdominant) bed composition within suitable spawning habitat will be more likely to support highest relative densities of spawners and is assigned a density coefficient (D) = 1;

5) "cobble/gravel" and "gravel/boulder" (dominant/subdominant) bed composition with otherwise suitable spawning conditions will support relatively lower densities of spawners due to greater likelihood of patchy substrate quality and departures from the conditions preferred by female salmon and is assigned a D = 0.5 [2];

6) "gravel/fines," "cobble/fines," and "cobble/boulder" (dominant/subdominant) bed compositions within otherwise potentially suitable spawning habitat will likely provide marginal conditions and support only the lowest spawner densities and is assigned a D = 0.1 [2].

[1] The largest reported ratio for defended space of 4 times the area of completed redds was selected to be conservative for estimating the number of spawners; however, the actual level of territoriality and defended space for winter run salmon in their current or historic spawning areas is uncertain.

[2] Departures in the bed substrate composition from mixtures most often preferred by salmon or when preferred mixtures are found in patchy distributions on pool tailout and riffle features will likely lead to higher incidences of females digging multiple redd pits and simply less of the total area of the feature accommodating spawners, leading to lower spawner densities. The coefficients proposed are educated guesses for relative ratios of expected declines in spawner densities due to these factors, based on relationships between redd densities and substrate size reported for other California streams (Upper Yuba River Studies Program 2007; Campos et al. 2013).

These parameters and associated assumptions can be combined to estimate the spawner capacity (number of pairs) using the following expression:

$$\sum_i H_i \cdot \frac{1}{Aterr} \cdot D_i,$$

where, *i*, indicates each delineated spawning habitat feature within a designated survey reach.

These estimates of salmon spawning habitat and spawner capacity for the upper Sacramento River can be compared to estimates for historic conditions reported by Hanson et al. (1940), who provide reach level estimates for Delta to Flume Creek reach and Flume Creek to Cantara Loop reach (Table 9).

Table 9. Historic Spawning Ground Survey Data, with Estimated Spawning Capacity, for the Upper Sacramento River from Delta to Cantara Loop

Stream Section	Length (feet)	Average Width (feet)	Estimate Percent of Streambed Suitable for Spawning	Estimated Utilization in Numbers of Female Salmon
Delta to Flume Creek	79,200	80.0	1.20	1,919
Flume Creek to Cantara Loop	86,592	57.0	0.93	1,147

Source: Hanson et al. (1940)

Although Hanson et al. (1940) also provided similar survey data for the McCloud River, such a historic comparison would be less informative for the purposes of this habitat assessment and design of a pilot reintroduction study because of the significant alterations to the McCloud River that have occurred since that time as a result of construction and operation of the McCloud-Pit Hydroelectric Project. A more useful corroboration may be made using the results of Pacific Gas and Electric Company's recent mapping and modeling of potential spawning habitat for salmon and steelhead (PG&E 2012 – Technical Memoranda #80 and #81). Representatives from Pacific Gas and Electric Company offered to make available survey data from these analyses that may be used for comparison or to augment data and analysis to be developed by this assessment.

Estimates of weighted usable salmon spawning habitat at selected flows or under a range of flows in the lower McCloud River from PG&E's Physical Habitat Simulation Model may be divided by the A_{terr} parameter to generate a corroborative estimate of a number of spawners that may potentially be supported under existing hydroelectric project operating conditions.

Assumptions and Uncertainty

Several key assumptions are explicit in our approach to this habitat assessment to address some limitations of existing information on the listed winter-run Chinook salmon that is the focus of this study and the uncertainties associated with reintroduction of a species to its former historically occupied habitat.

1) It has been nearly 75 years since anadromous salmonids had access to the study streams, and although habitat was known to be suitable for them at that time, it is uncertain how changes in habitat conditions since that time may affect suitability of habitat for reintroduced salmon under present conditions.

2) Changes in ecological conditions and species composition of the study streams have occurred since the blockage of anadromous fish by construction of Shasta Dam and the effects of these species on habitat suitability for Chinook salmon is uncertain.

3) While the existing distribution and abundance of coldwater fish in the study streams indicates that habitat remains very suitable for these populations and support highly valued sport fisheries, the response of reintroduced salmon, in terms of habitat use and preferences, in the presence of the existing coldwater fish populations is uncertain.

4) Growth and production of existing coldwater fisheries in the study streams can be used as an indicator of habitat suitability for growth and production of juvenile Chinook salmon.

5) While there is some variability and localized adaptation of habitat preferences among salmon stocks and races, the range in suitability of various habitat attributes is fairly consistent across the entire geographic range for individual species, such that use of the selected key habitat attributes and suitability criteria derived from other Chinook salmon races and regions for characterizing conditions of the study streams will provide information useful for planning a pilot-level reintroduction study, during which refinements to habitat assessment can be made.

Schedule

The proposed schedule for this habitat assessment is intended to develop data and analyses to inform development of the pilot-level reintroduction study plan over next 14 months, which is scheduled for completion by the end of 2014.

September 2013

- Complete draft Habitat Assessment Framework

- Meet with Habitat Subcommittee to discuss Habitat Assessment Framework
- Plan and schedule aerial videography
- Plan and schedule field site surveys

October –November 2013

- Conduct aerial video surveys and post-processing in GIS
- Conduct field site surveys and begin data compilation and analysis
- Prepare and circulate outline for draft Habitat Assessment technical memorandum

December 2013 – January 2014

- Finish data processing and compilation
- Conduct data analysis and prepare draft Habitat Assessment technical memorandum
- Schedule and circulate interim draft analyses to Habitat Subcommittee

February – March 2014

- Address comments on draft Habitat Assessment technical memorandum
- Finalize Habitat Assessment technical memorandum